



ALUFOOT®

ALUMINIUM INNOVATIONS FOR TIMBER BUILDINGS

CALCULATION MODE FOR ALUHD23/SH18®

Traction and shear aluminium plate for Alufoot® system

INTRODUCTION

ALUHD23/SH18® plate, being part of Alufoot® system, is used in order to connect the CLT wall to the Alufoot® aluminium beam. HD23/SH18 geometry has been optimized in order to withstand both the shear forces and the traction forces. We suggest to apply them at the beginning/end of the wall. Below you can find the report of the strength verification of the plate, following Eurocode 9, using the limit state design, that leads to the definition of the design strength field compared to the ultimate limit state

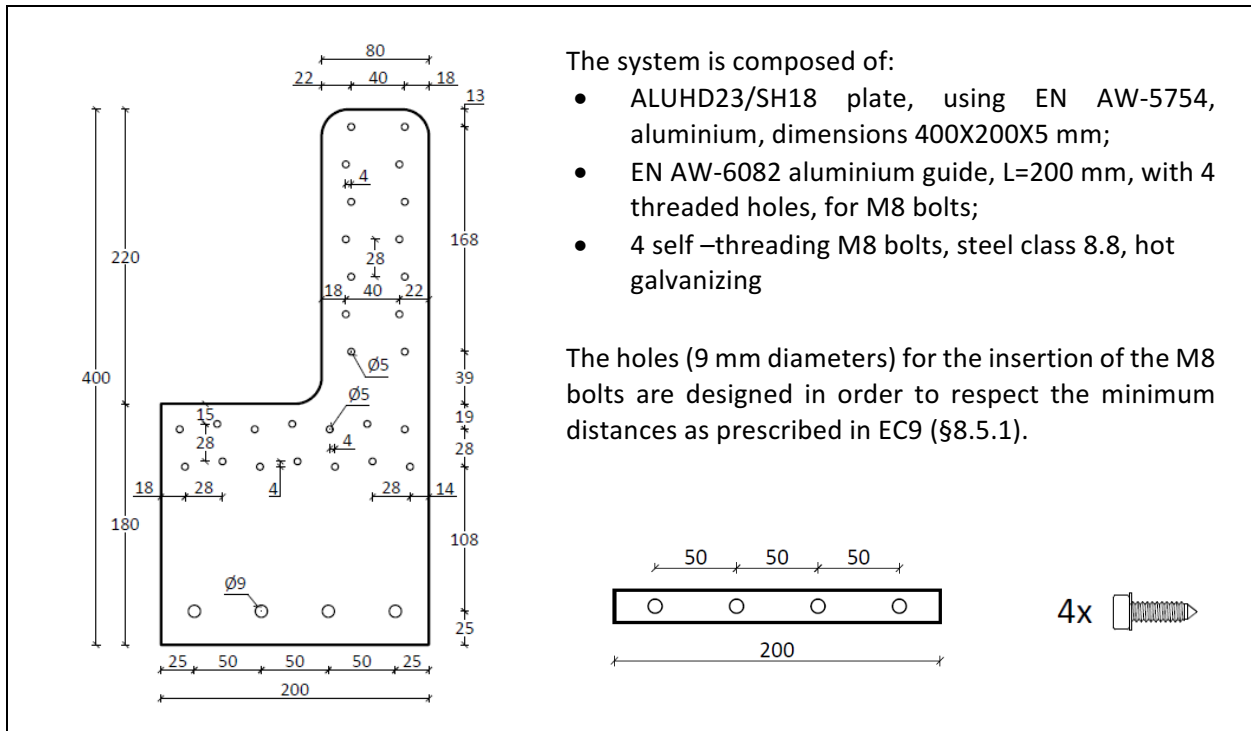
Strength verification is led with the only attention to the failure modes on the metal side (*metal side verification*). Strength verifications of the plate fastening to the timber wall (*timber side verification*) are left to the designer, being subject of many design variables, such as class, wooden type, service class, period of the load, type of fasteners.

SET OF RULES

Eurocode 9 - EN 1999-1-1 (EC9 below)

Eurocode 3 - EN 1993-1-8 (EC3 below)

GEOMETRY AND MATERIALS



Pic. 1: Geometry of HD23/SH18 plate

MATERIAL STRENGTH

According to EC9, for EN AW-5754 it is correct to use the characteristic strength values below:

- Yielding: $f_o=80$ MPa
- Failure: $f_u=190$ MPa

According to EC3, for steel class 8.8 bolts the characteristic strength values below are assumeable:

- Yielding: $f_{yb}=640$ MPa
- Failure: $f_{ub}=800$ MPa

The Eurocodes provide the safety factors below:

- Aluminium ductile failure (EN 1999-1-1 §6.1.3) $\gamma_{M1}= 1.10$
- Aluminium brittle failure (EN 1999-1-1 §6.1.3) $\gamma_{M2}= 1.25$
- Bolts (EN 1993-1-8 §2.2) $\gamma_{M2}= 1.25$

SECTION CLASSIFICATION

The section classification of the plate is calculated according to §6.1.4 of EC9. For HD23/SH18, section A level (see pic. 2) we have:

- $\beta = 0,4 b/t = 0,4 \cdot 200/5 = 16$
- $\varepsilon = \sqrt{(250/80)} = 1.77$
- $\beta/\varepsilon = 9.05$

And for section C (see pic. 2):

- $\beta = 0.4 b/t = 0.4 \cdot 80/5 = 6.4$
- $\varepsilon = \sqrt{(250/80)} = 1.77$
- $\beta/\varepsilon = 3.62$

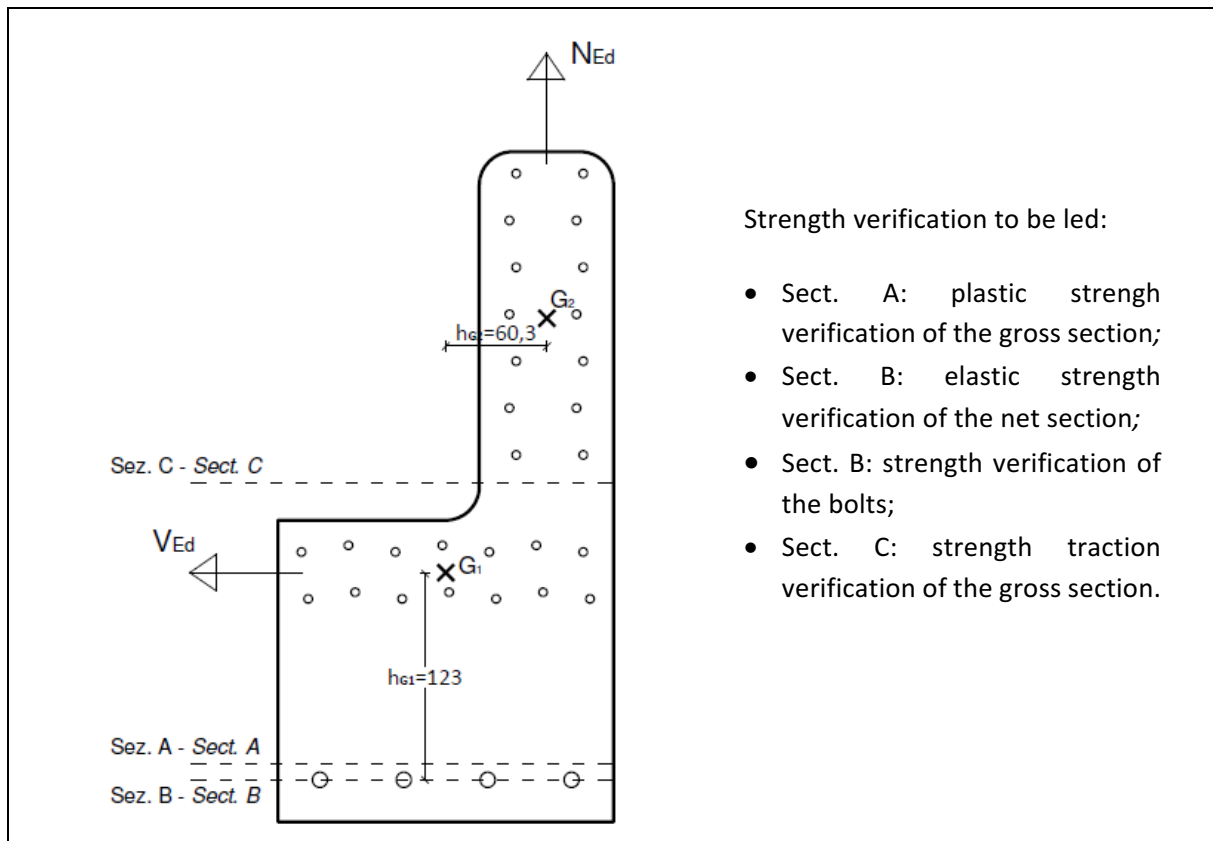
In both cases the section class is 1, according to table 6.2 of EC9. For that class the ultimate strength of the section can be calculated with reference to the ultimate limit state of plastic failure.

DESIGN HYPOTHESIS

The design hypothesis is that the total design force pass through the mass center G of the nailing on the timber wall (see pic. 2). This assumption results the most cautionary compared to the strength verification of the plate and of the bolts (metal side verifications).

STRENGTH VERIFICATIONS

The set of strength verifications to be led is illustrated in Picture 2. The strength domain of the plate, in terms of design forces N_{Ed} (traction) and V_{Ed} (shear) will be determined by the weakest strength mechanism.



Pic. 2: Strength verifications to be led

The bolts are fixed to the aluminium profile through an aluminium sliding bar, that is put into the specific pit realized on the profile.

Experimental tests have shown that the fixing system is over-resistant compared to the bolts, as the failure always comes for the slicing of the bolt on the contact section between plate and aluminium guide.

Section A: plastic strength of the gross section

Because of the geometry of the plate and the material behaviour, the quantities below must be defined:

- Maximum traction strength:

$$N_{o,Rd} = A_g f_o / \gamma_{M1} = 1000 \cdot 80 / 1.10 = 72.73 \text{ kN}$$

- Maximum shear strength:

$$V_{o,Rd} = A_g f_o / (\sqrt{3} \gamma_{M1}) = 1000 \cdot 80 / (\sqrt{3} \cdot 1.10) = 41.99 \text{ kN}$$

- Maximum moment strength:

$$M_{o,Rd} = W_{pl} f_o / \gamma_{M1} = 1/4 \cdot 5 \cdot 200^2 \cdot 80 / 1.10 = 3.64 \text{ kNm}$$

Because of the calculation hypothesis, the design moment is the sum of the two moments obtained by the multiplication of the shear force and the traction force with their eccentricities:

$$M_{Ed} = |V_{Ed}| \cdot h_{G1} + |N_{Ed}| \cdot h_{G2}$$

where h_{G1} is the distance between the center of mass of the shear resistant nailing and the bolts center of mass, equal to 123 mm, while h_{G2} is the distance between the center of mass of the traction resistant nailing and the bolts center of mass, equal to 60.3 mm.

For the composition of shear and traction forces the designer must follow the disequation below:

$$\frac{N_{Ed}}{N_{o,Rd}} + \frac{|V_{Ed}| \cdot h_{G1} + |N_{Ed}| \cdot h_{G2}}{M_{o,Rd}} \leq 1 \quad (I)$$

where V_{Ed} is the shear force and N_{Ed} the traction force on the plate, calculated for USL combination.

EC9 provides the verification (I) with a design strength reduced, equal to $f_{o,V} = f_o(1 - \rho) = f_o(1 - (2V_{Ed}/V_{Rd} - 1)^2)$, whenever it is verified the condition $V_{Ed} > 0.5V_{o,Rd}$. For shear forces over than 21 kN, the strength domain for the gross section, is characterized by a soft bending.



Section B: verification of the net area of the plate

Because of the geometry of the plate and the material behaviour, the quantities below must be defined:

- Maximum traction strength:

$$N_{u,Rd} = 0.9A_{net}f_u/\gamma_{M2} = 0.9 \cdot 830 \cdot 190/1.25 = 113.54 \text{ kN}$$

- Maximum shear strength:

$$V_{u,Rd} = A_{net}f_o/\sqrt{3}\gamma_{M1} = 830 \cdot 80/\sqrt{3} \cdot 1.10 = 34.85 \text{ kN}$$

- Maximum moment strength:

$$M_{u,Rd} = W_{net}f_u/\gamma_{M2} = 2.8 \cdot 10^6 \cdot 190/1.25 = 4.26 \text{ kNm}$$

Once determined the values of $N_{u,Rd}$, $V_{u,Rd}$ e $M_{u,Rd}$, the strength domain is obtained by the same considerations as the previous paragraph, by following the disequation:

$$\frac{N_{Ed}}{N_{u,Rd}} + \frac{|V_{Ed}| \cdot h_{G1} + |N_{Ed}| \cdot h_{G2}}{M_{o,Rd}} \leq 1 \quad (\text{II})$$

where h_{G1} is the distance between the center of mass of the shear resistant nailing and the center of mass of the bolts, equal to 123 mm, while h_{G2} is the distance between the center of mass of the traction resistant nailing and the bolts center of mass, equal to 60.3 mm.

As before, there is an interaction between the shear force and the traction force: for shear values $V_{Ed} > 17.4 \text{ kN}$, the verification (II) has been led assuming the reduced design strength tension $f_{o,V}$, in the same way as done for the strength verification of the gross section.

Section B: strength verification of the bolts

The shear strength of the single bolt M8 cl. 8.8 ($V_{b,Rd}$) is the minimum between the burr strength of the aluminium plate and the slicing strength of the bolt, given by the expressions below:

- Slicing strength of the bolt

$$F_{V,Rd} = \alpha_V \cdot \frac{f_{ub}A_s}{\gamma_{M2}} = 0.6 \cdot 800 \cdot \frac{36.6}{1.25} = 14.05 \text{ kN}$$

- Burr strength

$$F_{b,Rd} = k_1\alpha_b \cdot \frac{f_u dt}{\gamma_{M2}} = 2.5 \cdot 0.926 \cdot 190 \cdot 8 \cdot \frac{5}{1.25} = 14.07 \text{ kN}$$

From the previous expressions it comes that the shear strength of the bolt is equal to:

$$V_{b,Rd} = \min\{F_{V,Rd}; F_{b,Rd}\} = 14.05 \text{ kN}.$$

The design strength domain of the bolts, in terms of shear forces V_{Ed} and traction forces N_{Ed} , has been determined according to the following expression:

$$V_{b,Ed} = \sqrt{\left(\frac{N_{Ed}}{4} + \frac{(V_{Ed} \cdot 123 + N_{Ed} \cdot 60.3) \cdot 75}{(75^2 + 25^2)}\right)^2 + \left(\frac{V_{Ed}}{4}\right)^2} \leq V_{b,Rd}$$

which verifies that the shear force on the most forced bolt results minor than the shear strength.

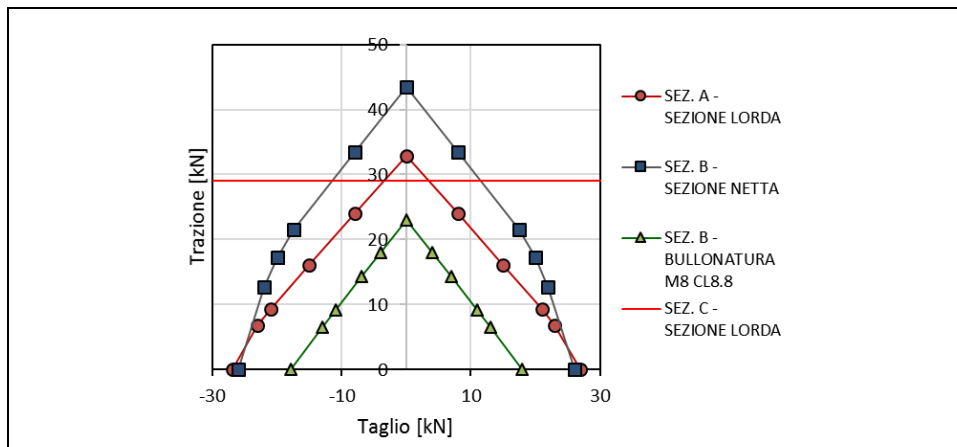
Section C: traction verification of the gross section

Because of the geometry and the characteristics of the aluminium (defined by EC9), the maximum design traction strength of the plate, at section C level, is equal to:

$$N_{o2,Rd} = A_{g2}f_o/\gamma_{M1} = 400 \cdot 80/1.10 = 29.09 \text{ kN}$$

REPRESENTATION OF THE STRENGTH DOMAINS

The four verifications lead to the creation of three domains, represented in Pic. 3:



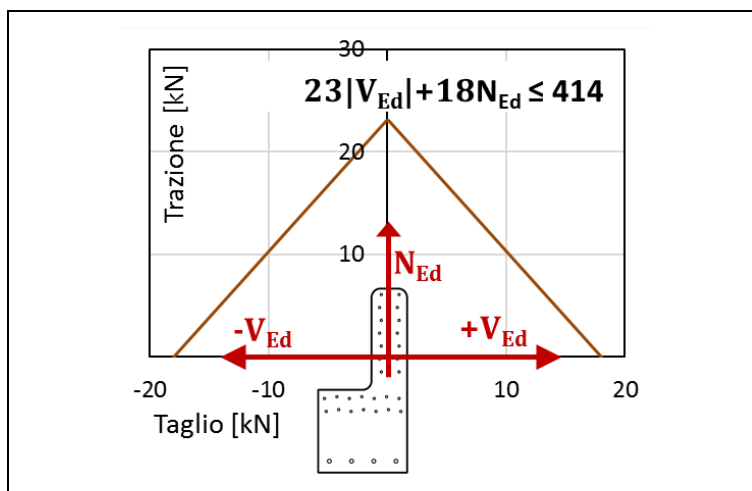
Pic. 3: Results obtained by the strength verifications.



DESIGN STRENGTH DOMAIN OF THE PLATE (METAL SIDE)

The design domain for ALUHD23/SH18 is well described by the disequation:

$$23|V_{Ed}| + 18N_{Ed} \leq 414 \text{ kN}$$



Pic. 4: Graphic representation of the design strength domain